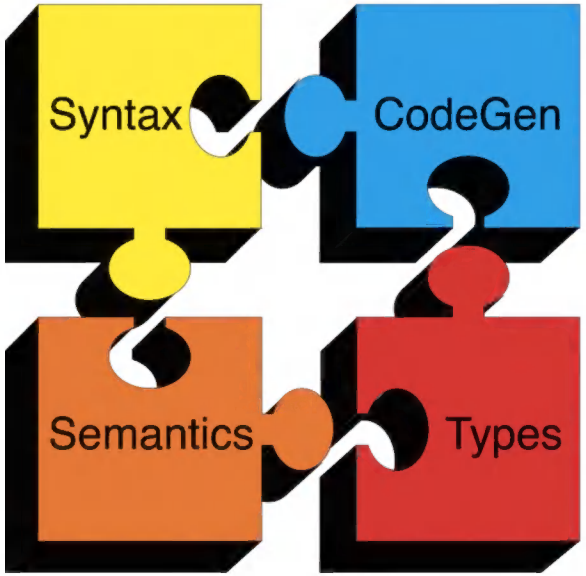

Compilers

Optimization Overview

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Optimization Overview

- Optimization is our last compiler phase

- Most complexity in modern compilers is in the optimizer
  - Also by far the largest phase

Optimization Overview

- When should we perform optimizations?
  - On AST
    - Pro: Machine independent
    - Con: Too high level
  - On assembly language
    - Pro: Exposes optimization opportunities
    - Con: Machine dependent
    - Con: Must reimplement optimizations when retargetting
  - On an intermediate language
    - Pro: Machine independent
    - Pro: Exposes optimization opportunities

Optimization Overview

$P \rightarrow S\ P \mid S$

$S \rightarrow$ id := id op id
| id := op id
| id := id
| push id
| id := pop
| if id relop id goto L
| L:
| jump L

- Id's are register names
- Constants can replace id's
- Typical operators: +, -, *

- A basic block is a maximal sequence of instructions with:
  - no labels (except at the first instruction), and
  - no jumps (except in the last instruction)

- Idea:
  - Cannot jump into a basic block (except at beginning)
  - Cannot jump out of a basic block (except at end)
  - A basic block is a single-entry, single-exit, straight-line code segment

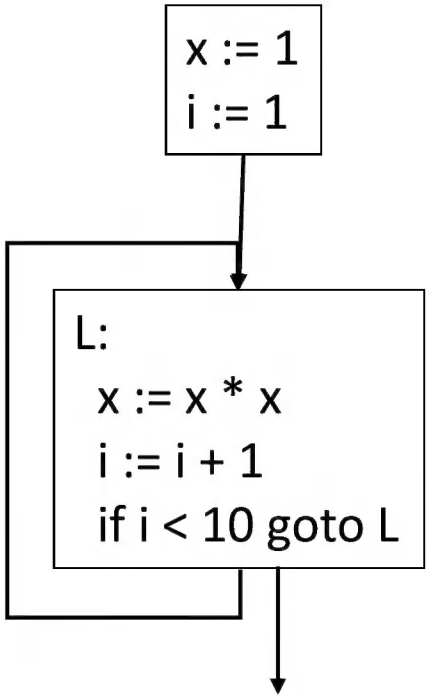
- Consider the basic block

```
1. L:
2.    t := 2 * x
3.    w := t + x
4.    if w > 0 goto L'
```

- (3) executes only after (2)
  - We can change (3) to w := 3 * x
  - Can we eliminate (2) as well?

- A control-flow graph is a directed graph with
  - Basic blocks as nodes
  - An edge from block A to block B if the execution can pass from the last instruction in A to the first instruction in B
    - E.g., the last instruction in A is jump L_B
    - E.g., execution can fall-through from block A to block B

Optimization Overview



- The body of a method (or procedure) can be represented as a control-flow graph
- There is one initial node
- All "return" nodes are terminal

Optimization Overview

- Optimization seeks to improve a program's resource utilization
  - Execution time (most often)
  - Code size
  - Network messages sent, etc.

- Optimization should not alter what the program computes
  - The answer must still be the same

Optimization Overview

- For languages like C and Cool there are three granularities of optimizations
  1. Local optimizations
     - Apply to a basic block in isolation
  2. Global optimizations
     - Apply to a control-flow graph (method body) in isolation
  3. Inter-procedural optimizations
     - Apply across method boundaries

- Most compilers do (1), many do (2), few do (3)

Optimization Overview

- In practice, often a conscious decision is made not to implement the fanciest optimization known

- Why?
  - Some optimizations are hard to implement
  - Some optimizations are costly in compilation time
  - Some optimizations have low payoff
  - Many fancy optimizations are all three!

- Goal: Maximum benefit for minimum cost